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CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Ft. Belvoir, VA, technically managed by the Air Force Research Laboratory Human Effectiveness Directorate, Wright-Patterson Air Force Base, OH, and operated by Booz-Allen & Hamilton, McLean, VA.



Figure 1. Artist's conception of how VCATS will integrate a pilot's helmet with an aircraft's sensors and seekers. Pilots can aim weapons at any target in view, not just those in front of the aircraft.

Human-Centered Design Project Revolutionizes Air Combat

Laima Rastikis

The successful integration of technology and human factors meets its ultimate challenge in the area of military performance. Nowhere are the stakes so high and the competition so rigorous as in the arena of combat.

Within the US Air Force, the Crew System Interface Division (formerly the Fitts Human Engineering Division) of the Air Force Research Laboratory has led the effort to meet this critical challenge since 1945, longer than any human-factors engineering laboratory in the world.

One of the division's most important

programs has resulted in a technological breakthrough that is revolutionizing the way US pilots fight in air-to-air combat. Chief project engineer Dean Kocian has been the driving force in the development of this initiative for some 20 years.

Since machine guns were first mounted on airplanes in World War I, pilots have had to point the nose of their aircraft in the direction of the target. The dynamics of airborne combat required pilots to outmaneuver each other. Superior aircraft speed and agility were the keys to a successful engagement.

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A Better Chance of Beating the Adversary

Now, that scenario has changed. The Visually Coupled Targeting and Acquisition System (VCATS) (see Fig. 1) uses new technologies to provide warfighters in a close-in air battle a better chance of beating the adversary—if only by a few seconds—to a missile launch point for the first shot or an exclusive kill opportunity. The advantage of those few extra seconds could save the pilot's life.

VCATS has made it possible to technologically synthesize target information the pilot sees in a helmet-mounted display with a computer in the cockpit and the capabilities of onboard advanced weapons. Sensors on the pilot's helmet track the position of the pilot's head as it follows the target through the display in the helmet visor. The sensors relay critical information to the computer, which in turn, communicates the location of the target to the missile system. When the weapons lock on to the target, the pilot receives both audio and video signals, and then pulls the trigger located on the control stick. The missile is fired.

R&D Goal: Advantage in the End-Game

This scenario represents a total paradigm shift in the way air-to-air combat is fought. The sighting reference for cuing a weapon is no longer the nose of the aircraft, but rather the pilot's helmet. As long as the target is within range, and can be viewed by the pilot through the display in the helmet visor, the relative position of the aircraft to the enemy is not critical. The tactical implications are profound.

VCATS also represents a human-factors breakthrough. For several decades, increased propulsion and maneuverability were paramount in Department of Defense-sponsored technical research aimed at improving the US fighter pilot's advantage in the end game. Yet airframe and power-plant enhancements were becoming so ad-

vanced that they sometimes surpassed the pilot's tolerance of the associated physical stresses. New levels of aircraft speed and agility placed the pilot in the position of pulling G's at dangerously high levels of up to 12, a maneuver that can produce devastating results such as blackouts.

With the system newly developed by Kocian and his team, however, the pilot continues to be limited to nine G's while the missile may pull in excess of 50 G's enroute to its target. This human-centered system matches the pilot's physical and mental capabilities—the visual system, head-eye-hand coordination, decision-making abilities and response time—to the specially developed hardware and software.

VCATS incorporates a standardized helmet-vehicle interface that uses five interconnecting modules which are easily replaced with minimal effort, down-time, or potential for error. Through the helmet and its connectors, the pilot becomes part of a closed-loop electronic system.

Human-factors Breakthrough

The pioneering of VCATS stems from 30 years of research and development for the US Department of Defense, by the Visually Coupled Systems and Visual Interface Laboratory of the Crew System Interface Division. The lab is located in the Human Effectiveness Directorate of the Air Force Research Laboratory at Wright-Patterson Air Force Base near Dayton, Ohio.

Implementation of the system has been accelerated in recent years, partly in response to the fact that Soviet, Israeli, and other air forces have had less sophisticated systems since the mid-1980s.

VCATS technology is based on a visually coupled system: a head-mounted imaging device that relays information to and receives feedback from the viewer. In the case of VCATS, a 4.3-pound helmet/head tracker and display provides the pilot with data on altitude, speed, and other flight fea-

tures, along with target information within a wide field-of-view. Dynamic images are projected by a miniature cathode-ray tube onto the helmet's visor (see sidebar, p. 3).

Visually coupled systems have been developed by Kocian's team through years of system and component tests and human-factors experiments to solve the problems of integrating the helmet-mounted display with the human visual system and advanced weapons systems. Parallel advancements in conventional technologies such as the miniaturization of the cathode-ray tube and development of the magnetic helmet tracker have supported the accelerated implementation of VCATS.

Watching for "Situation-awareness Suckers"

In February 1997, VCATS was taken out of the laboratory and into the sky for testing at the 422 Test and Evaluation Squadron (TES) at Nellis Air Force Base, Nevada. The F-15 was equipped with advanced weapons systems, the helmet-mounted tracker and display, a telemetry data collection system, an onboard data collection system, including videotaping capabilities, and other key technologies. A core group of six combat-qualified pilots flew the tests. They were chosen for their superior skill, familiarity with the full scope of hardware and software dimensions, ability to assess the system in terms of its compatibility with future strategies, and the validity of their operational assessments.

The opportunity to test VCATS in a tactical air-combat environment—as opposed to a simulator or developmental test aircraft that flies limited tactical profiles without the real and limiting physical stresses of flight during air combat—has proven invaluable to the system-design and test program. Detailed findings about the design and human use of such systems can only be ascertained in near-combat conditions by combat-qualified pilots. Researchers' evaluations were based on

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Testing in Near-combat Conditions Critical to Success

This graphic identifies the major system components used in the testing of the Visually Coupled Acquisition and Targeting System (VCATS) at Nellis Air Force Base, Nevada, in February 1997. The system was tested in the F-15 fighter aircraft flown by combat-ready pilots.

VCATS uses a daytime helmet-mounted tracker and display to follow the pilot's line-of-sight. Also included is a panoramic night-vision goggle featuring a head-up display that allows the pilot to view critical flight symbology through an overlay on the goggle. The helmet-mounted tracker and display of the VCATS-equipped aircraft track the pilot's head movements and provide real-time information about the orientation of the radar

and any active weapon seekers. This affords the pilot a unique cuing and targeting capability. The helmet-head tracker measures the pilot's line-of-sight and transmits this information to onboard weapons, sensors, and display systems. As a result, the pilot can sight and designate targets based solely on head movement. Previously, this could only be accomplished by orienting the aircraft and its radar toward the target. Thus VCATS offers the pilot a great tactical advantage.

The configuration of the VCATS operational utility evaluation at Nellis included standard test-range telemetry data collection using wing-mounted pods and special self-contained data-collection hardware onboard. It also includes a high-speed

interface between the helmet and weapon seeker which utilizes the -35 PACS upgrade shown in the figure. The configuration is robust enough to permit the evaluation of critical human-factors engineering criteria, the collection of supporting data, and the evaluation of new technology in a tactical air-combat environment.

The ability to operate in a tactical environment, as opposed to a simulator or ordinary test aircraft, is a key element of the system design and test program. The more ambitious test process is providing new and unique findings about the design and human use of such systems—findings that can only be ascertained by combat-qualified pilots under near-combat conditions.

data from the onboard digital instrumentation and videotapes, the subjective comments of the pilots, and aircraft maintenance issues resulting from the test flights.

Because of the pilot's central role in the VCATS system, great care was taken to watch for *situation-awareness suckers*, any slight distraction caused by the equipment that would diminish the pilot's performance.

Testing Evaluates Human, Operational Dimensions

After 24 test flights, the warfighters' evaluations were positive, testimony to the many human-factors engineering challenges that have been overcome in the development of VCATS. Some of those challenges are listed below.

Human-factors challenge: Both traditional ways of reflecting an image off a helmet visor into a pilot's eye have disadvantages. One way uses a reflective patch that blocks out close-in targets during air combat. Another way uses a highly reflective transparent coating that blurs distant targets.

Solution: System developers solved this problem by creating a new miniature hot-tube CRT that provides greater brightness, contrast, and resolution as well as a quadruple-speed refresh rate. Because of higher brightness, Kocian's team used a much-less-reflective coating on the entire inside of the visor to provide seamless viewing and minimize obscurity of both close or far targets. The team also took Air Combat Command's direction to consider maintenance and logistics issues. Thus the new CRT was fitted with a novel connector that:

- could be disconnected quickly in the shop;
- could operate safely at the lower atmospheric pressure of high altitudes without hazardous arcing; and
- was self-tuning to compensate for production-line variances.

This solution is another example of how creative improvements to hardware can be used to solve human-factors engineering problems. The demonstrated commitment of the team not to compromise pilot requirements led to hardware improvements that allowed an otherwise unacceptable system to be implemented.

Human-factors challenge: The helmet must strike the balance between stability and comfort. Weight must be kept to a minimum to prevent excessive pressure or burning sensations on the pilot's head. Improvement of the center of gravity is also an issue considering that a four-pound helmet represents 36 pounds of weight when a pilot pulls nine G's.

Solution: To prevent pilot discomfort, some components have been made lighter. The hot-tube CRT, for example, includes lightweight connectors and a lighter seal. A procedure for trimming the bottom edge of the visor to fit snugly against the oxygen mask was developed with the 422 TES personal equipment shop to increase the stability of the helmet at high G's while eliminating the need for uncomfortably tight helmets. Also, specially developed flexible cables weigh 70

percent less than those used in previous versions of the helmet.

Human-factors challenge: The helmet-mounted display assembly must be easily removable so that the pilot may switch, when necessary, to a night-vision goggle. This feature is also important for support personnel who are responsible for equipment maintenance.

Solution: The helmet-vehicle interface has been the focus of significant effort by Kocian and his team (see Figs. 2 & 3). Their work has resulted in the development of a revolutionary universal helmet connector that integrates a specially-developed mechanical latching system and automated power supply shutdown that allows the pilot's safe and easy in-flight removal of the helmet, even while high-voltage power is still being applied. The special design allows the pilot—even with gloved hands—to precisely align the connector pins of both the daytime and nighttime vision systems. The helmet-vehicle interface incorporates the following human-factors engineering features:

- The system is designed to recognize whether the daytime or nighttime display is plugged in. This self-recog-

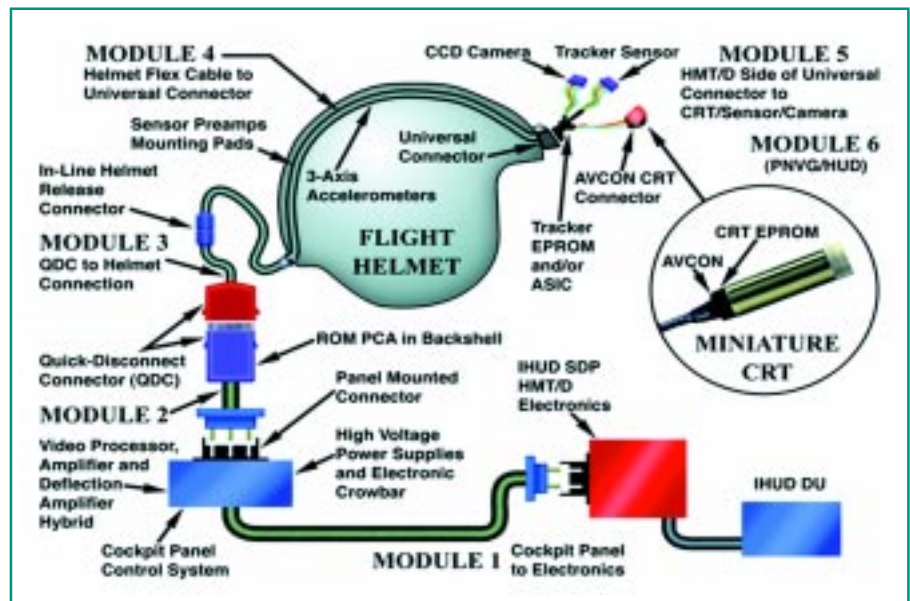


Figure 2. Helmet-vehicle interface schematic diagram.

nition feature automatically adjusts the associated software, requiring no switching or reconfiguration by the pilot.

■ Standardization provides flexibility for product improvements by alternate vendors.

■ Modularity and self-recognition features facilitate replacement of failed cathode-ray tubes, tracker sensors and miniature cameras with only a screwdriver. No soldering, disordering, alignment, or testing is needed.

Human-factors challenge: The helmet cable, which contains 60 signal conduits, must not restrict the pilot's head movement. Conventional shielding that blocks interfering electrical signals also significantly stiffens the cable.

Solution: A special, woven Kevlar™ shield surrounds the pilot-to-aircraft cable, its individual fibers plated with copper and then nickel or silver. The shield was developed with Reynolds Industries Inc. and the DuPont Corporation. The new super-flexible cable has improved shielding for stray electric fields and does not deteriorate after repeated flexing as does conventional cable shielding.

Human-factors challenge: The helmet must meet all requirements for protecting the pilot's head from impact and penetration.

Solution: VCATS uses a high-density helmet liner that doubles the protection to the head from impact.

Human-factors challenge: The pilot's performance in cuing a target and achieving a rapid missile lock-on during an airborne engagement is diminished by the effects of head bounce experienced under certain aircraft-buffeting conditions.

Solution: Helmet-mounted accelerometers and high-update rate-trackers provide the capability to sense, process, and compensate for large and

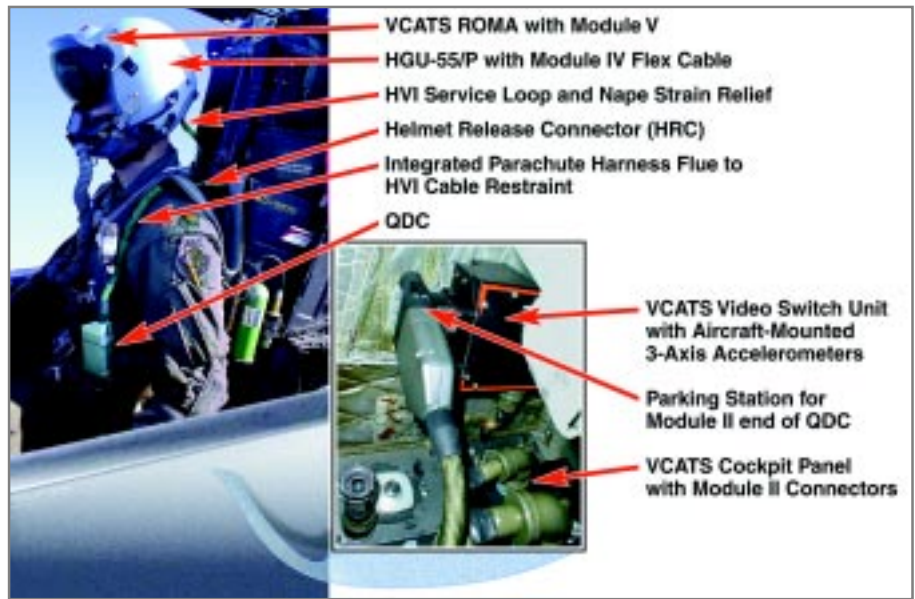


Figure 3. Actual implementation in the F-15C cockpit.

small head movements. The technology has been designed to fit into the standard flight helmet using the new, energy-absorbing liner that accommodates the range of head sizes that normally fit into the standard helmet.

Human-factors challenge: In air-combat situations, the pilot must be able to accomplish safe and unassisted ejection and rapid ground egress in explosive-vapor environments.

Solution: The quick-disconnect connector is an integral part of the helmet-vehicle interface design. The high-voltage connector is mounted on the pilot's torso. It transports electrical power, video signals, control signals, and position and orientation signals of the helmet-mounted tracker to and from the helmet and cockpit control panel. The connector automatically disconnects when the pilot rises from the seat for rapid ground egress from the cockpit or when the seat moves during a seat ejection. A helmet-release connector provides for safe separation of the helmet from the pilot should helmet loss occur during in-flight ejection.

Human-factors challenge: The effects of restriction of the pilot's head movements by the ejection seat, life-

support equipment, and effects of high G on the head/neck position must be overcome.

Solution: An innovative technique for providing multiple cuing references on the helmet visor (first accomplished during the Laboratory's Virtual Panoramic Display Program that supported the Army LHX program) was assessed during the 422 TES tests. Pilots are currently evaluating whether the multiple cuing references are valuable in obtaining a first-shot, exclusive-kill potential under high G.

Future Directions

Portions of the VCATS technology—specifically, government-furnished equipment under the VCATS contract—are currently being transitioned into selected Navy's F-18s, the Army's RAH-66 Comanches, and the Air Force's F-22s, F-15s, and F-16s.

As for the VCATS system, further refinement proceeds, with research focused on the potential use of fiber optic cable, the incorporation of high-definition digital television, color symbology in the helmet-mounted tracker and display, and a

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new, panoramic, night-vision goggle head-up display system.

The transition successes achieved in the VCATS program are due primarily to a close working relationship with the specific warfighters who eventually will use similar technology in combat. Fighter pilots have recognized the advantages the system affords them and have sought to ensure that lessons learned are carried over into the USAF acquisition program where completion of preproduction hardware is underway.

An outstanding example of human-centered design, VCATS advances the Crew Systems Interface Division's mission to maximize the

potential of Air Force warfighting personnel. The division's primary goal is to link-via human-system integration -technological advances in controls, displays, and information-handling with the military pilot's human factors, including sensory, perceptual, cognitive, and motor capabilities; strength and anthropometrics; experience; and skills.

While new and exciting technologies will continue to enhance US military capabilities in the future, the technological and human-factors breakthrough developed by Kocian and his team for VCATS is nothing short of revolutionary. It will be considered for many years as one of the most dramatic innova-

tions in airborne combat since machine guns were first mounted on aircraft some 80 years ago. ●

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Dear CSERIAC...

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts. These questions were compiled by Debra Urzi, Human Factors Engineer. If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway*.

■ A research company requested hand and arm (reach) anthropometric data for use in cellular telephone design.

■ A research institute contacted CSERIAC to obtain data regarding the new KC-135 cockpit/glare shield and the implications of nuclear flash entering via the thermal curtain.

■ A representative of the US Air Force requested CSERIAC's help in locating a source for lifting restrictions in regard to pregnant women.

■ A representative of a major defense contractor in the US midwest requested information on shiftwork.

■ A disability access specialist in California requested building-code accessibility standards.

■ A member of the US Air Force working in the aerospace medicine field requested data on aircraft vibration and testicular cancer levels.

■ A representative from a large university in the western United States contacted CSERIAC to locate anthropometric data for physically fit females to be used for clothing design.

■ A management information systems specialist from a corporation in Florida requested information on the design of automated voice messaging systems.

■ A chief scientist from a research company in the midwest requested information on task analysis models.

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Calendar

June 20-26, 1998 Seattle, WA, USA

16th International Congress on Acoustics & 135th Meeting of the Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797. Tel: +1-516-576-2360, Fax: +1-516-576-2377, Email: asa@aip.org

June 22-26, 1998 Washington, DC, USA

Usability Professionals' Association 1998 Conference. Contact: Cara Martin, Prestige Accommodations, 2603 Main St., Suite 690, Irvine, CA 92614. Tel: +1-800-321-6338, Fax: +1-714/752-7444, Email: prestigacc@aol.com, WWW: http://www.upassoc.org/html/1998_conference.html

July 13-17, 1998 Los Angeles, CA, USA

UCLA Extension will present the short course, "Advanced Cockpit Displays." Contact Marcus Hennessy. Tel: +1-310-825-1047, Fax: +1-310-206-2815, Email: mhenness@unex.ucla.edu, WWW: <http://www.unex.ucla.edu/shortcourses/>

July 20-21, 1998 Madison, WI, USA

New Concepts in Medical Device Design Workshop. Contact Professor Mike Waxman, Engineering Registration, Dept. 106, The Wisconsin Center, 702 Langdon Street, Madison, WI 53706. Tel: +1-800-462-0876 or +1-608-262-1299 (TDD 265-2370); Fax: +1-800-442-4241 or +1-608-265-3448; Email: custserv@epd.engr.wisc.edu, WWW: <http://epdwww.engr.wisc.edu/>

August 9-12, 1998 Maui, HI, USA

2nd International Conference on Engineering Design and Automation. Contact Hamid R. Parsaei, Dept. of Industrial Engineering, University of Louisville, Louisville, KY 40292. Tel: +1-502-852-1416, Fax: +1-502-228-6868, Email: htpars01@ulkyvm.louisville.edu

August 9-14, 1998 San Francisco, CA, USA

24th International Congress of Applied Psychology. Contact American Psychological Association, Office of International Affairs, 750 First Street, NE, Washington, DC 20002-4242. Fax: 202-336-5956, Email: icap@apa.org

August 19-22, 1998 The Hague, Netherlands

Sixth IEA International Symposium on Organizational Design and Management (ODAM 98). Contact Peter Vink, NIA TNO BY, PO Box 75665, NL-1070 AR Amsterdam, Netherlands; Fax +31-20-6441-450; Email: h.knijnenburg@nia-tno.nl

September 14-16, 1998 Elsinore (Helsingør), Denmark

2nd International Conference on Aging and Work. Contact Ole Teller, Danish Working Environment Fund, Vermundsgade 38, DK-2100 Copenhagen, Denmark. Email: amfudd@inet.uni-c.dk

September 14-16, 1998 Phoenix, AZ, USA

SAFE Association 1998 Symposium. Contact SAFE Association, 107 Music City Circle, Suite 112, Nashville, TN 37214. Tel: +1-615-902-0056, Fax: +1-615-902-0077. *Abstracts due July 24, 1998.*

September 14-19, 1998 Seattle, WA, USA

16th International System Safety Conference. Contact System Safety Society, PO Box 70, Unionville, VA 22567-0070. Tel: +1-540-854-8630, Fax: +1-540-854-4561, Email: syssafe@ns.gemlink.com, WWW: <http://www.system-safety.org>

October 2-4, 1998 Baltimore, MD, USA

Inter-Society Color Council Annual Meeting. Contact ISCC, 11491 Sunset Hills Road, Reston, VA 20190. Tel: +1-703-318-0263, Fax: +1-703-318-0514, Email: iscc@compuserve.com *Abstracts due June 1, 1998.*

October 5-9, 1998 Chicago, IL, USA

42nd Annual Meeting of the Human Factors and Ergonomics Society. Hosted by the Chicago Metropolitan Chapter. Contact HFES, PO Box 1369, Santa Monica, CA 90406-1369; Tel: +1-310-394-1811, Fax: +1-310-394-2410, Email: hfes@compuserve.com, Web: <http://www.hfes.org>

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AFRL/HEC/CSERIAC Bldg 196, 2261 Monahan Way, Wright-Patterson AFB OH 45433-7022

The Director's Corner

Matt Kolleck

UNDER NEW MANAGEMENT! That's right, the Crew System Ergonomics/Human Systems Information Analysis Center (CSERIAC) is under new management. On December 12, 1997 Booz-Allen & Hamilton Inc. was awarded the CSERIAC contract. Core operations under Booz-Allen began on January 29, 1998.

As the new CSERIAC Director, I would like to acquaint you with Booz-Allen & Hamilton Inc. and present our vision of the new CSERIAC, as well as how we intend to get there. Booz-Allen is one of the largest technology and management consulting firms in the world, with over 7,000 employees located in 70 offices in 40 countries on 6 continents.

Booz-Allen operates three other IACs, the Information Assurance Technology Analysis Center (IATAC), the Survivability/Vulnerability Information Analysis Center (SURVIAC), and the Shock and Vibration Information Analysis Center (SAVIAC).

Our vision for CSERIAC is one of expansion throughout the Department of Defense, including the various services, other federal agencies and departments, and to commercial entities, and the international community. We intend to do this initially by leveraging the existing client base within the firm and its infrastructure. We will market the CSERIAC Technical Area Task (TAT) program to the various Science & Technology (S&T) Programs, Program Executive Officers (PEOs) and Program Managers, and other Government Agencies within this client base.

Our vision is also one of increased

participation and activity within the ergonomics/human factors community. We intend to pursue this through:

- participation in the various ergonomics/human factors professional organizations;

- participation, both through paper presentations and exhibition, at one conference/symposium per month;

- establishment of a Liaison Point-of-Contact (POC) Program; and

- sponsorship of appropriate workshops.

The Liaison POC Program is an innovative one in which Government organizations remote from CSERIAC designate a POC to come to CSERIAC and receive one week of specialized training on the various CSERIAC databases, products, models, and library. Benefits from this program include the development of closer ties between CSERIAC and the user community as well as the opportunity for data collection and dissemination. If you would like

more information on this program, or any of the other items mentioned above, please contact me.

We envision CSERIAC playing a critical, all-encompassing role in maintaining and developing methods for the collection and analysis of Crew System Ergonomics and Human Factors Technology scientific and technical information. In other words, we will provide the right information to the right people at the right time!

Matthias Kolleck is the Director of the CSERIAC Program Office.

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- Safety and risk assessment
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- Virtual reality simulations
- Analyzing group processes
- Working posture analysis
- Time and motion studies
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Words From the Chief Scientist

Michael Fineberg

My name is Michael Fineberg. I've recently joined Booz-Allen & Hamilton as Chief Scientist for the new CSERIAC. In this position I will be responsible for overall quality control of CSERIAC products and services, for the development and definition of technical area tasks, and for ensuring that our products and services are available throughout the human factors community. Since you'll be hearing quite a bit from me in future issues of *Gateway*, I would like to introduce myself and tell you about my vision for CSERIAC.

For over 30 years I have served as a research psychologist and technical manager devoted to enhancing human performance in stressful situations. My expertise includes human capabilities and limitations; human-computer integration; human-performance-related factors; and display, control, and workplace design. My most recent contributions have included the development of a theory of human performance under stress, and modeling the effects of nuclear radiation, chemical-biological weapons, and suppressive fire on combatant performance.

In addition to serving in government and industry, I have been a professorial lecturer at local universities, a family psychotherapist in private practice, and a consultant on psychological stress for private schools and small businesses. I'm a member of the Human Factors and Ergonomics Society and was President of the Potomac Chapter in 1979. I'm also a member of the American Psychological Association, a fellow of the Maryland Psychological Association, and a fellow of the Inter-University Seminars on Armed Forces and Society. I earned my Ph.D.

in Applied Experimental Psychology at Catholic University and did post-doctoral work in systems theory at Georgetown Medical School.

My work experience includes 20 years in the professional services industry, as well as 10 years in the US Department of Defense. Some might view my varied experience as an inability to hold a job. I like to see it as a noble quest for new challenges! Speaking of challenges, I've taken the liberty of describing some of my more memorable ones in the following paragraphs.

In the area of crew system ergonomics, I conducted several full-scale human factors and system safety programs including ones for the F-14A aircraft, SH-3H helicopter, and Harpoon missile system. Subsequent to the Three Mile Island accident, I managed the Nuclear Regulatory Commission's detailed human factors and safety review of all US nuclear power plant control rooms.

While working for the Naval Air System Command, I designed work stations, instrument panels, controls and displays, and human-computer interfaces, and helped to develop devices to enhance cognitive performance and situation awareness and, for the Air Force, I investigated pilot factors in fighter aircraft accidents. To verify my designs and experimental results, and to be sure I understood the environment in which I worked, I flew numerous test flights as a certified technical observer in the F-4, S-2F, OV-10A, CH-53, and UH-1E aircraft at the Naval Air Test Center and Troy Army Airfield.

With regard to human-system technology, I developed a theory and taxonomy of human performance under stress to construct "human-like" synthetic forces for use in advanced

distributed simulations. I also measured pilots' navigation performance during more than 200 hours of nap-of-the-earth helicopter flight, receiving an Army commendation for this work because of its importance to the Army and because of its hazardous nature. Subsequently, I continued this navigation research in the lab!

In other studies I identified soldiers' psychological responses to the threat of conventional, nuclear, and chemical warfare, measured pilot performance in a helicopter simulator after exposure to a medically supervised protocol simulating the effects of nuclear radiation illness, and measured the effects of various doses of gamma-neutron radiation on the physical, psychomotor, and cognitive performance of primates in free-running and restrained conditions.

I've also spent several years teaching. As a guest lecturer at Georgetown Medical School, I taught psychiatry residents, and lectured on cognitive and visual perception, experimental psychology, and management of patient distress. At George Mason University, I taught a course in industrial training and I am currently a professorial lecturer at George Washington University's School of Engineering, teaching Human Factors Engineering.

Now what about this new CSERIAC? Over the years I have consulted CSERIAC and was quite satisfied with the help I received. But, it was not until recently that I understood that CSERIAC is open to all services, to all government agencies, and in fact to all those in industry and academe who wish to employ its services. Furthermore, it was not until I became Chief Scientist that I realized I could have conducted complete research and development

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projects within CSERIAC. At that time I had my first CSERIAC attack, "You mean I could have used CSERIAC all those years?" After mourning the lost time and wasted money, I made up my mind to acquaint all of you with CSERIAC's capabilities. Therefore I will take CSERIAC on the road, as it were. When your interest in our products and services warrants it, we will open CSERIAC satellite offices in research and development centers such as McLean, VA; Lexington Park, MD; Orlando, FL; and San Diego, CA.

My vision is for a human factors community in which we all know about CSERIAC, know how to contact it, and know how to make use of its free basic inquiry service, its free network of subject-matter experts, and its sizable catalog of software tools and publications. My vision also includes a human factors community that provides feedback to CSERIAC about the quality of its products and services, and submits its research results and

models for storage in our database. In other words, my vision for CSERIAC is that it will be what it was always supposed to be, your "one-stop shop" for human factors information.

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Michael Fineberg, Ph.D., is the Chief Scientist for the CSERIAC Program Office

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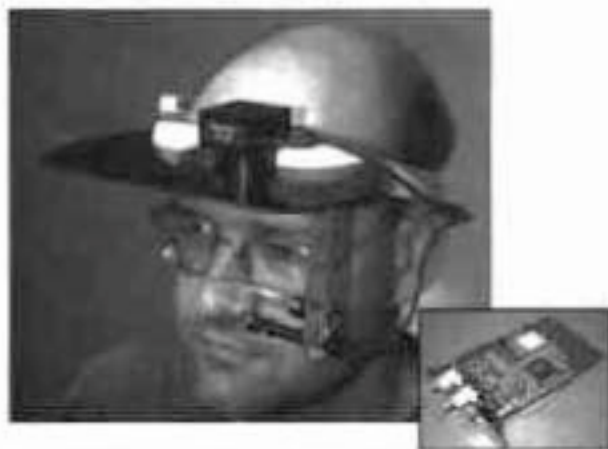
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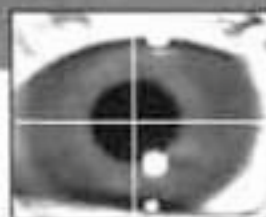
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Air Force Research Laboratory Human Engineering Division Colloquium Series Situation Awareness, Automation, and Decision Support: Designing for the Future

Mica Endsley

Editor's note: Following is a synopsis of a presentation by Dr. Mica Endsley, then with Texas Tech University, but currently with SA Technologies, Atlanta, Georgia. She was the sixth speaker in the 1996 Armstrong Laboratory Human Engineering Division Colloquium Series: Human Technology Integration. This synopsis was prepared by Michael Reynolds, Senior Human Factors Engineer, CSERIAC Program Office. JAL

Situation Awareness (SA) was for many years a research topic limited to aircraft cockpits. It remains a critical cockpit issue; in reviews of Navy and National Transportation Safety Board (NTSB) records, Endsley found a lack of SA to be a leading cause of accidents in both military and commercial aviation. However, in recent years, SA has become a research topic in other important fields such as surgical medicine, nuclear power control, air traffic control, and aircraft maintenance systems. This broadening has occurred because of research which shows that SA is a defining factor in human performance and with quality SA comes good decision making and, consequently, good human performance.

Endsley defined SA as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Cockpit SA is made up of five major categories of elements: geographical, spatial/temporal, system, environmental, and tactical. Each of these major categories has multiple sub-elements. For example, geographical SA includes own aircraft, other aircraft, airports, and navigation fixes. Spatial/temporal SA

includes altitude, heading, velocity, and projected flight path, to name a few. System SA includes system-related factors such as fuel and system settings. Environmental SA factors comprise such things as temperature, visibility, and projected weather conditions. Finally, tactical SA encompasses items such as identification, threat flight dynamics, and threat imminence.

A Model of SA

Endsley presented a framework model (see Fig. 1) showing the factors impacting SA, including task/system (e.g., system capacity, interface design, automation) and individual (e.g., goals and objectives, experience, expectations). For novices and novel situations, SA and decision making are limited by attention and working memory. Experts generally have de-

veloped better mental models, have better knowledge (of critical cues, components, etc.), and have the benefit of automaticity (processing without conscious awareness).

The Research

The model in Figure 1 was applied to NTSB accident data. Based on 24 accident reports (period 1989-1992), the majority of human errors resulted from a lack of SA. These were categorized into Level 1, 2, and 3 SA errors (per the definition shown in Fig. 1). The error distribution was 78%, 17%, and 5%, respectively, for Levels 1, 2, and 3. For clarification, a Level 1 error implies that the human did not perceive the information; a Level 2 error means that the human did not assimilate the information perceived; and a

continued on page 12

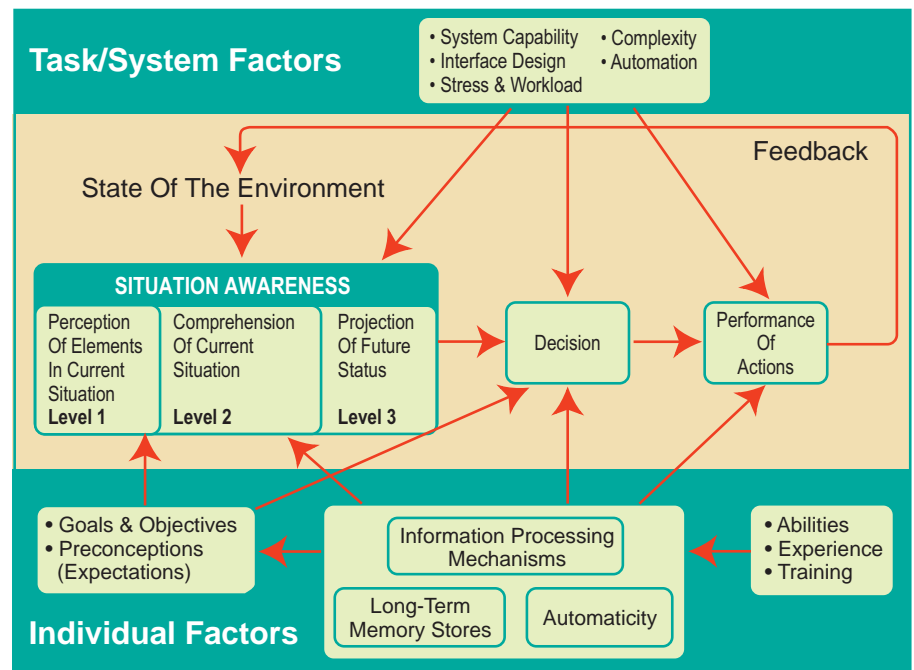


Figure 1. Endsley model of situation awareness with factors that impact.

Level 3 error indicates that the human had the information, assimilated the information, but was unable to project a future state.

Because the NTSB sample size was very small, Jones and Endsley (1996) examined the Aviation Safety Reporting System (ASRS) database for additional information on SA errors in aviation; 140 reports were studied and 252 SA errors were identified. Figure 2 shows the types of ASRS errors observed by level of error.

The most prevalent Level 1 error was failure to monitor/observe needed information at approximately 45 percent. Endsley discussed several of the factors that contributed to the failure to monitor/observe SA error. The main factor in the failure to monitor/observe was other task distractions; other factors included vigilance, stress, workload, and reliance on automation. Level 2 errors were dominated by the use of the incorrect mental model. Limitation in the nature of the self-reported data of ASRS prevents further detailed examination of the data, especially the Level 3 errors.

SA Examined

Factors which impact SA include stress (physical, social and psychological), workload (over- and underload), system design (a major area of concern due to the lack of integration of information), system complexity, and automation. Endsley believes that historically the research has focused too much on the workload/overload problem without examining other aspects, such as underload.

Automation Design

The rest of Endsley's presentation was on designing automation and decision-support systems, and their impact on SA. Again, historically, SA has been thought of as a problem brought on by heavy workload. Thus, the solutions to date have been directed at reducing workload through increased automation and intelligent

LEVEL 1	LEVEL 2	LEVEL 3
<ul style="list-style-type: none"> • Information not available • Information hard to discriminate/detect • Failure to monitor/observe • Misperception • Memory loss 	<ul style="list-style-type: none"> • Lack of or incomplete mental model • Use of incorrect model • Over-reliance on defaults • Other 	<ul style="list-style-type: none"> • Lack of or poor mental model • Over-projection of current trends • Other

Figure 2. Observed errors by level of error.

interfaces (integration/fusion, filtering, and decision support). The result, in many cases, is simply a workload shift and a significant loss in SA and overall system skills which result in another distinct problem known as the "out-of-the-loop" problem. Traditional automation approaches focus on the overload problem without taking into account human involvement and awareness. Highly complex systems have resulted which do not allow the human to develop a clear mental model. The difficulty lies in integrating the human and system decision making with the development of decision-support systems. Research shows that the addition of decision-support systems can actually slow decision making without improving the quality of decisions made.

The question is whether automation actually reduces workload. There is literature indicating that automation does NOT reduce workload and may, in fact, increase workload (Bainbridge, 1983; Harris, et al., 1994; Riley, 1994; Wiener, 1985). Thus, a dilemma exists. Because workload is high, we add automation, but the result is only a shift in type of workload and not a

reduction. Further, significant losses in SA may result from "out-of-the-loop" performance problems. Often additional automation is added and a vicious cycle continues. The designer must ask the question "When is performance good?" The answer is "Performance is good when humans are involved in the tasks and aware of the situation, but not overloaded."

Therefore, a look at alternative approaches to automation is warranted. One may look at a change in level of automation, flexible function allocations, intelligent interfaces, and the provision of better information. A study by Endsley and Kiris (1995) involving five levels of automation (no automation, decision support, consensual artificial intelligence [AI], monitored AI, and full automation) was conducted. It was found that in an automation failure condition, human decision-making time increases with level of automation. Further, when reviewing Level 2 SA errors, the percentage of errors was greatest in the full automation condition. This study suggests looking at intermediate levels of automation.

Endsley also discussed other research involving levels of automation (LOA)

based around a distribution of roles (monitoring, generating, selecting, and implementing) to the human or computer or both. A computer-based monitoring and target elimination task was conducted to examine effects associated with varying levels of automation (Endsley & Kaber, in press). It was found that during normal operating modes, performance improved with LOA involving computer aiding in the *implementation* aspect of task functioning. Conversely, performance decreased at LOA involving joint human-computer strategy *generation*. In an automation failure mode, subjects experienced a decreased ability to recover when LOA increased.

Endsley concluded that focusing on workload reduction through increased automation is conceptually flawed. She pointed out that current human performance problems and automation can be linked to traditional approaches involving attempts to reduce workload. Thus the question becomes "What aspects of automation should be examined in future designs?"

Endsley suggests that future automation approaches focus on keeping the operator involved and at a high level of SA; in other words, do not simply give the operator just data. Designers should focus on the development of integrated systems and integration based on operator goals, and provide automation that supports SA.

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Naval Air Warfare Center Aircraft Division Environmental Physiology and Human Performance Laboratory

Jonathan Kaufman

The Environmental Physiology and Human Performance Laboratory (EPHPL) at the Naval Air Warfare Center Aircraft Division, Patuxent River, Maryland is responsible for physiological research and development, and product support related to Naval and Marine Corps aircrews. Collaborative agreements with other services, other US agencies, academia, industry and foreign governments expand the benefits of this work to the broader community. Results from the numerous thermal and respiratory physiology, human factors, clothing, and materials studies performed in this and predecessor laboratories over more than 50 years have saved lives, increased readiness, and saved the Navy and US taxpayers millions of dollars.

The EPHPL can trace its roots to physiological laboratories located at the Philadelphia Navy Yard, Philadelphia, Pennsylvania and the Naval Air Development Center, Warminster, Pennsylvania. Work in these laboratories included pioneering efforts in acceleration, pressure suits, weightlessness, and cold-water immersion protection. Much of the training for the original seven Mercury astronauts was conducted in these facilities. Early, full- and partial-pressure suits for high performance Naval aircraft were also developed in these laboratories. Among the more notable research undertaken at Johnsville, PA (later renamed Warminster, PA) was skin burn investigations performed by Dr. Alice Stoll and Dr. James Hardy's work investigating human physiological responses to thermal stress.

In the mid 1970's these laboratories were consolidated at Warminster. Among the many significant accomplishments were heat stress and cold



Figure 1. Assessing heat stress prior to launch of the Space Shuttle by simulating an 8 hour pre-launch environment in the EPHPL environmental chamber.

water immersion certification trials on the NASA Space Shuttle crew garments (see Fig. 1), and identifying methods for aircrew to recover control of F-14 aircraft during flat spins. The laboratories remained at Warminster until relocating to the Naval Air Station, Patuxent River, Maryland in 1996. Recertification of the EPHPL was completed on March 11, 1997.

Research at the new EPHPL facility can perform a wide range of studies exploring human physiology and performance in stressful environments. The intent is to provide scientific support for the development of Fleet-related personal protection systems while also performing state-of-the-art research to advance Navy capabilities. Active programs in the new facility

can be divided into thermal physiology, human performance, respiratory physiology, acceleration physiology, and material testing.

Thermal physiology studies include test and evaluation of clothing ensembles, personal cooling systems, advanced glove systems, and life rafts as well as research into hypothermia rewarming techniques and how the ambient environment affects cognitive and psychomotor performance. These studies have directly contributed to naval aviation by aiding in the development of the current CWU-62/P anti-exposure coverall, LRU-18/U one-man life raft, and AR-5 chemical, biological, and radiological head/eye/respiratory protective system. Currently, the EPHPL is involved in developing improved

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cooling systems and a successor to the USN Mk 1 CBR protective ensemble. In addition, the EPHPL has worked with NASA to certify that the current Space Shuttle protective suit meets heat stress and anti-exposure requirements. EPHPL has also worked with the Air Force and Coast Guard in cold-water immersion studies (see Fig. 2).

Human performance studies focus on the relationship between thermal stress and changes in human cognitive and psychomotor performance. Recently, a functional F-18 flight simulator was installed in the EPHPL environmental chamber to study the effect of environmental stressors on aircrew performance. This simulator is linked to an identical simulator in the Advanced Crew Technology Laboratory (ACTL), also located at the Naval Air Warfare Center, Patuxent River, permitting investigators to study how cockpit environments affect aerial combat performance by having subjects in the chamber and ACTL fly against each other.

The EPHPL also studies human/clothing/environment interaction by simulating human physiological responses to temperature extremes with a mathematical model of human thermal responses based on the University of Texas thermal model. The original Texas model has been expanded by including gender differences and refining some of the general physiological assumptions. Data acquired from EPHPL human thermal studies and the open literature are used to validate model predictions.

Mathematical modeling supplements clothing studies conducted on the EPHPL thermal manikin, a fully articulated thermal manikin with 30 independently heated and controlled body segments, and the Laboratory's guarded hot plate. The guarded hot plate provides a relatively simple means of measuring material heat transfer properties of dry or wet flat clothing swatches. Thermal manikin measurements more accurately estimate whole clothing ensemble thermal proper-

ties because these measurements account for clothing shape and fit effects on overall heat exchange. Data obtained from these devices are used as thermal model input parameters and to characterize proposed clothing materials and ensembles.

In the area of respiratory physiology, work has focused on predicting airway particle deposition and its relationship to airway heat and water vapor exchange. Navy interest lies in assessing the physiological threats that combustion products and chemical-biological weapons pose when inhaled and identifying agent physiochemical parameters relevant to injury. Developing a series of unique temperature probes for measuring human airway temperatures has been a critical element in the EPHPL series of human respiratory heat and water vapor exchange studies. Experimental data acquired in these studies is being used to enhance the University of Pennsylvania particle deposition model.

Work in acceleration physiology involves continuing studies on female accommodation and work capabilities in a high-G environment. This work utilizes the human flight

simulator in Warminster and has recently looked at the effects of added head weight and "push-pull" (negative-to-positive G forces) on human G tolerance. Push-pull effects have the potential to be a significant problem to the next generation of high-performance attack helicopters. ●

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Figure 2. Simulating an open ocean survival situation in the EPHPL cold water tank.



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